solar charging regulator

for panels up to 53 watts

A small solar power installation consists of at least three components, namely a solar panel, a storage battery and a charging regulator. The charging regulator limits the final charging voltage and also protects against reverse current flow.

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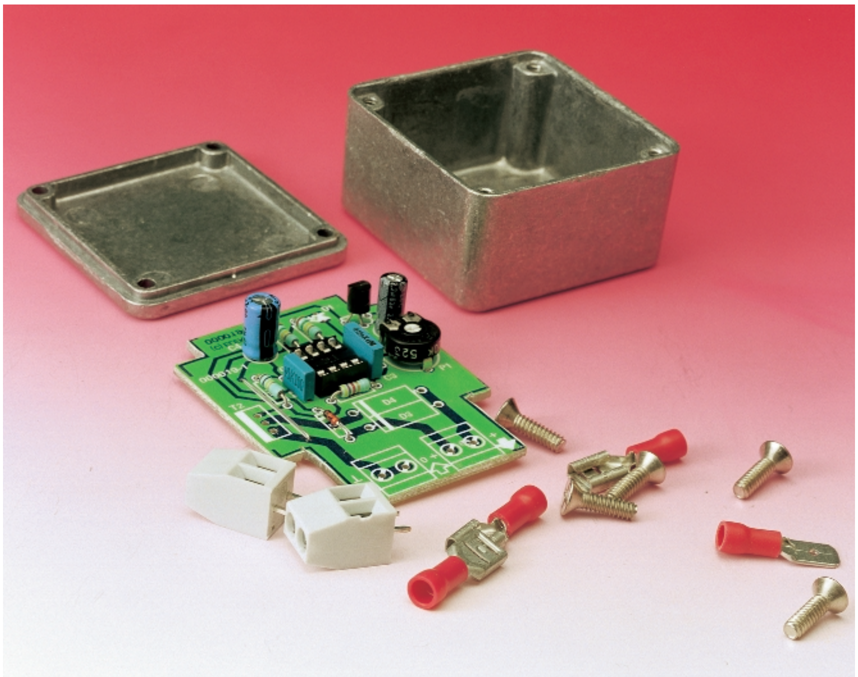

Specifications of the solar charging regulator

Supply voltage	*12 V, from the battery*
Solar panel	*up to 53 W*
Operating current	*2.1 mA*
Voltage drop	*0.43 V at 3 A*
Temperature range	*–10 to +45 °C*
Short-circuit and reverse-polarity protected	

If you were thinking that nothing new has appeared in *Elektor Electronics* in the last ten years regarding solar power technology, this article is the proof!

In a self-contained solar power installation that can provide electrical energy even when the weather is bad or it's dark outside, an energy reservoir in the form of a lead-acid battery is indispensable. In order to prevent the battery from being discharged via the solar panel when the terminal voltage of the panel drops below the actual level of the battery voltage, reverse-current protection is necessary. In its most rudimentary form, such a 'solar current valve' is just a simple diode. A Schottky diode, which has a low forward voltage drop, is normally used to minimise losses.

Unfortunately, the terminal voltage of a 12-V solar panel is significantly higher than its nominal rated voltage when it is illuminated by strong sunlight, so it is not possible to avoid exceeding the fully-charged (terminal charge) voltage of the battery using only this single diode. If the voltage applied to the battery is too high, it produces gas, which reduces the lifetime of the battery and can also be dangerous, since the gas is explosive. A regulator circuit is thus necessary, in addition to the reverse-current protection diode, to limit the terminal charge voltage of the battery to 2.30 V per cell (equivalent to 13.8 V for a 12-V battery).

The regulator circuit presented here fulfils these two tasks — reverse current protection and voltage regulation — in an elegant manner.

SHORT-CIRCUIT CONTROL

In the circuit diagram of the regulator, shown in **Figure 1**, it's easy to identify the reverse-current protection. If the terminal voltage of the battery is higher than that of the solar panel, the Schottky diode D3 prevents any current from flowing from the positive terminal of the battery to the positive terminal of the solar panel, independent of the state of the rest of the circuit. In the reverse situation, the charging current has free access to the battery. The voltage drop across the diode is 0.43 V at a current of 3 A.

However, the solar panel current can also flow through D4 and T2 when transistor T2 is switched on. The transistor is driven by the opamp IC1, which is wired as a comparator. Transistor T1 and potentiometer P1 provide

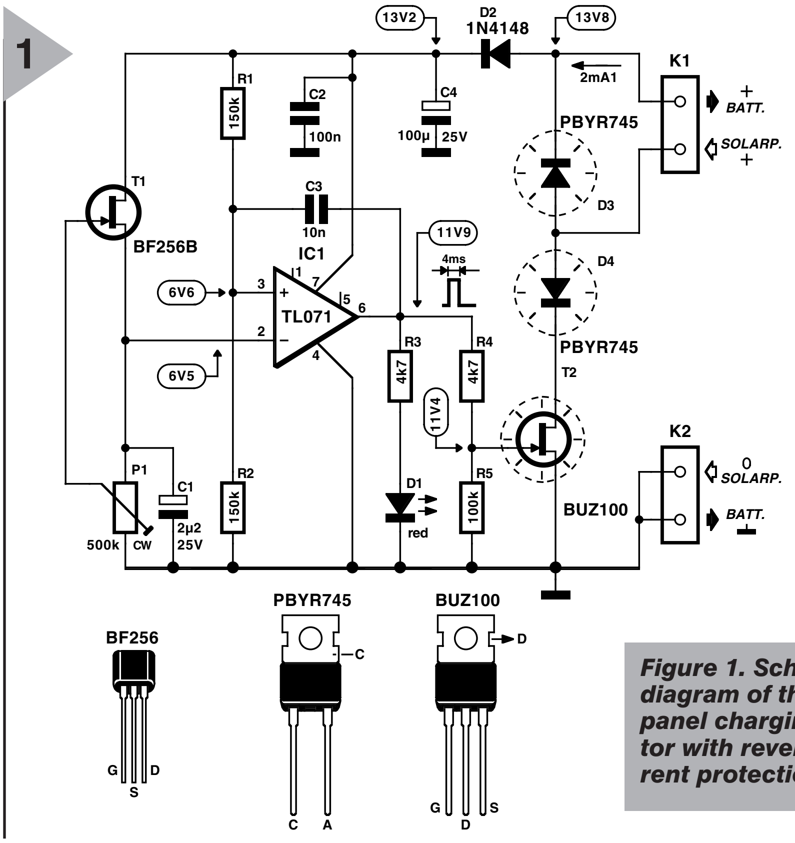

Figure 1. Schematic diagram of the solar panel charging regulator with reverse-current protection.

a reference voltage, which is filtered by capacitor C1. This voltage is set to roughly half of the terminal charge voltage of the battery. The opamp compares the reference voltage to the voltage at the junction of R1 and R2, which is half of the battery voltage less the 0.6-V drop of diode D2. The exact values are shown in the circuit diagram. If the battery voltage is less than the terminal charge voltage, the output of the opamp remains low and T2 is cut off. Led D1 is thus off, which indicates that the full solar panel current is flowing into the battery.

If the battery voltage rises above the terminal charge voltage, the comparator output changes to high (D1 on) and switches on T2, so that the output of the solar panel is short circuited. Since a solar panel represents a current source, which can deliver only a limited current even when it is strongly illuminated by the sun, this otherwise brutal form of shunt regulation is fully acceptable.

Nevertheless, an additional measure is used to minimise the power dissipation in T2 and D4, and thus avoid the need for a large heat sink. This is provided by capacitor C4, which produces a brief positive feedback pulse (lasting around 4 ms) to the opamp whenever it changes state. This significantly improves the switching behaviour of the opamp, so that the edges of the output signal are distinctly steeper.

The power dissipated by an n-channel MOSFET (such as the BUZ100) is the lowest when it is either fully on or fully cut off, or in other words when it passes either a high current or no current at all. In the 'analogue' region between these two extreme states, the power dissipation is much greater. The edges of the drive signal should therefore be as steep (and thus as short) as possible. This is precisely what C3 achieves.

When the charging current to the battery drops out, due the short-circuiting of the solar panel, the battery voltage drops slightly. This causes the comparator to switch states and allow the battery to be charged again. In practice, this means that the fuller the battery is, the faster the LED blinks.

PACKAGING

The solar panel regulator can be mounted in any suitably large enclosure. The small aluminium enclosure that is specified in the components list is particularly 'chic', since it not only protects the electronics against the external environment but can also serve as a heat sink for the three power semiconductors. Only the edge of the circuit board that holds the terminals protrudes through a slot in the enclosure.

To construct the board, first mount all the components, except for the terminals, on the printed circuit board shown in **Figure 2**. Insert the two Schottky diodes and the power tran-

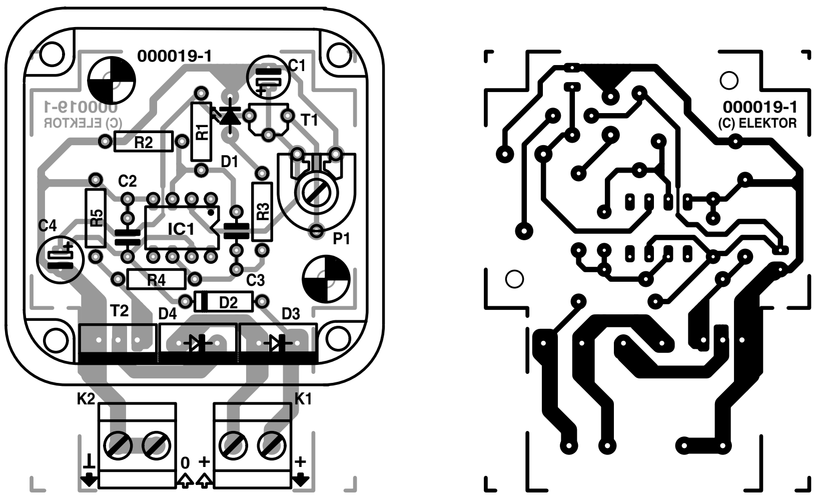

Figure 2. The circuit board fits exactly into the recommended enclosure.

COMPONENTS LIST

Resistors:
R1,R2 = 150kΩ
R3,R4 = 4kΩ7
R5 = 100kΩ
P1 = preset 500kΩ

Capacitors:
C1 = 2µF2 25V radial
C2 = 100nF
C3 = 10nF
C4 = 100µF 25V radial

Semiconductors:
D1 = LED, red, high efficiency
D2 = 1N4148
D3,D4 = PBYR745 (Philips)
T1 = BF256B
T2 = BUZ100* (Siemens)
IC1 = TL071CP or TL081

Miscellaneous:
K1,K2 = 2-way PCB terminal block, raster 5mm
Enclosure: Hammond 1590LB (50x50x32 mm)
PCB, order code **000016-1**, see Readers Services page and Elektor website.

sistor as far as possible into the board. Now you're ready for a first test. Turn P1 fully to the left and then connect an adjustable power supply (set to 13.8 V) to the battery terminals. Next, turn P1 slightly past its middle position. If the LED illuminates, the construction of the board should be OK.

If the LED does not behave as it should, check the two input voltages of the comparator opamp, and make sure that the comparator works properly for both input conditions.

By the way, the BUZ100 is nothing more than an improved version of the good old BUZ10 that can theoretically dissipate up to 250 W. This is naturally not at all necessary, so that a BUZ10 or BUZ11 transistor can be substituted for the BUZ100 if the latter is difficult to obtain. Similar considerations apply to the Schottky diode. Any type that can handle at least 3 A can be used.

DRILLING AND FILING

You will have to make a slot in the small aluminium enclosure through which the 'external' portion of the circuit board can be passed. The slot should 32 mm long and 6 mm wide. The circuit board is laid out such that the three power semiconductors lie flat against the inner wall of the enclosure. Mark and drill the two holes for fastening the board, and then mount the board in the enclosure using 5-mm stand-offs. Next, carefully measure and mark the holes for fixing the three power semiconductors, above the slot. Remove the board, drill 2.5-mm holes in the marked locations and tap them for an M3 thread.

The two Schottky diodes and the MOSFET transistor must be insulated from each other and from the enclosure. You can use mica or plastic insulators that are cut so that they fit next to each other and allow the lid of the enclosure to be closed.

Now remount the circuit board, and then check that the holes in the cooling tabs of the three power semiconductors exactly line up with the drilled holes. If they do not, you must either file down the stand-offs or lengthen them using thin shims. Only after all five holes line up can you tighten all the screws without generating mechanical stresses. Don't forget to use heat-sink paste on both sides of the insulators, and make sure that there is an insulating washer (with a collar) between the screw and the heat sink tab of each semiconductor. Be sure to check the results of your work using an ohmmeter! After everything has been proven to be properly insulated, mount the terminals on the circuit board.

Before you close the lid of the enclosure, you should adjust P1 while the regulator is connected to a real solar power installation (see **Figure 3**), with the regulator located as close as possible to the battery. This is necessary to take into account the voltage losses due to the terminal connections and the cables, which are significant even with relatively thick wires (diameter 1.5 mm or more), and thus achieve optimum performance of the installation. Do not forget to provide suitable fuses for both circuits, since a current of more than 100 A can flow in case of a short circuit!

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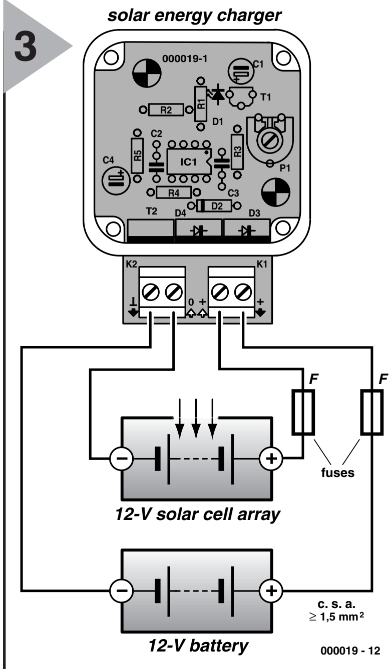

Figure 3. Integrating the regulator into a solar power installation.

Dimensioning a self-contained solar power installation

The individual components of a solar power installation must be properly dimensioned in order to optimally exploit the available energy. The ***current consumption*** *(including the losses in the solar regulator), together with the time behaviour of the current consumption, essentially determines the planning of the installation. Based on this information, you can calculate the average daily or weekly current consumption. In small solar power installations, with an average consumption of at most 3 kWh/day and a peak load of around 3 kW, you can usually assume a system voltage of 12 V. With heavier loads, a higher system voltage is recommended in order to keep the wire thickness and/or the wiring losses within reasonable limits. A voltage of 24 to 48 V, or even up to 230 V, can be obtained by connecting several solar panels in series.*

The next step is to estimate ***the required size of the solar generator****. The orientation of the solar panels and their angle with respect to the horizontal, the efficiency of the solar panels and naturally the geographic location of the installation (since the sun shines more often and more intensely in some places than in others) all enter into this calculation. The result is either the required nominal current capacity or, in the case of a given type of panel, the required number of panels (connected in parallel).*

Finally, you must determine the ***capacity of the storage battery****, which compensates for the climatic variations in the available solar energy. There are two criteria here, namely the already-determined average daily or weekly power consumption in ampére-hours and the number of days for which the installation must be able to supply power from the battery alone, which strongly depends on the individual application. The allowable discharge capacity of the battery must be taken into account here.*

In addition to these main criteria, there are several ostensibly secondary considerations that should be taken into account, such as the peak demand, the voltage reserve at high operating temperatures, the mechanical preparation of the modules, the available and required amount of space, costs, building code restrictions, subsidies and so on.

If you are seriously interested in the construction of a solar power installation, it is strongly recommended that you first read some introductory literature. There are also a number of more or less useful PC programs on the market to help in calculating the requirements for the components of a solar power installation. A good introduction to the subject is provided by the CD-ROMs Solar Power and Solar Craft from the Energiewende Verlag (www.solarenergie.com). These include a multimedia introduction, basic information, address directories, tips and tricks and simple construction information. Solar Power also includes a calculation program, while Solar Craft includes an interactive calculation program that guides you step by step through the construction of a domestic installation.